Usage of Solid Sources for Measurement of Electron Capture Ratios*

J. C. Palathingal

University of Michigan, Ann Arbor, Michigan, U.S.A.

University of Cincinnati, Cincinnati, Ohio, U.S.A.†

Abstract: Measurement of intensities of atomic X-rays using proportional counters has been the standard method of determining ratios of electron capture from atomic shells of low binding energy. Gaseous sources are employed in these experiments. The necessity of using gaseous sources is a serious disadvantage of this technique.

If a monatomic or submonatomic layer source, evaporated onto a low atomic number material is used inside a proportional counter, the intensity measurements can still be made with accuracy. The mean depth of penetration of the X-rays into the backing material is much larger than the range of the photoelectrons or Auger electrons produced by the X-rays. When the backing material is suitably chosen, the secondary X-rays emitted in these processes may also be ignored. For these reasons, the shape of the spectrum of X-radiation due to electron capture will not be substantially altered by the presence of the backing material.

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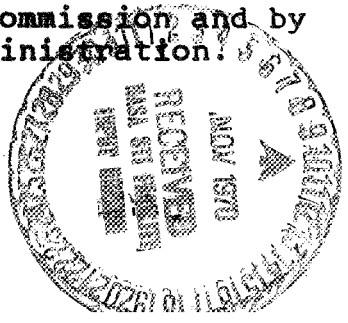

1. INTRODUCTION

In experiments for measuring the ratios of electron capture from atomic shells of binding energies of the order of a few keV or lower, the use of solid sources is not considered feasible. The standard practice in determining these ratios has been to measure the intensity of the atomic X-rays from the vacant electronic shells. Isotopes which could be produced in the gaseous state at room temperature conveniently could be studied using a proportional counter. The method is difficult and restricted, since gaseous sources cannot be readily obtained for all isotopes.

2. SOLID SOURCES

It is possible to use a solid source for measuring low energy X-ray intensities using a proportional counter if the source thickness is less than that of a monatomic layer. Self-absorption is not important for such a thickness. A critical analysis may be made of the factors introduced by the presence of the backing material, that may tend to complicate the determination of the ratios of intensities of X-rays from different atomic shells. From such an analysis, it can be shown that a backing material of low atomic number does not necessarily introduce any significant uncertainties of a new kind. Since the energy of the X-rays involved in such cases are only a few keV or less, most of the photons penetrating the backing material are photoelectrically absorbed. Because the range of the photoelectrons is much smaller than the mean depth of penetration of the photons

producing them, most of these electrons are absorbed before they enter the region of the proportional counter gas. The Auger electrons are also similarly absorbed within the backing material. The secondary X-rays produced in these photon-electron processes are of much lower energy than the primary radiation (through proper choice of the backing substance) and are therefore absorbed within the material. The few Compton-back-scattered photons have substantially the same energy as the unscattered ones.

For the above-stated reasons, the line shape of mono-energetic X-radiation recorded in a multichannel analyser will be essentially the same as when a gaseous source is used.

Although the absorption or scattering of photons in the source-backing material does not adversely affect the line shape of a single peak, an escape peak may be observed corresponding to each X-ray energy, even for high pressures of counter gas, because of detection in regions of the counter close to its walls. Another significant feature that may also be considered to be a serious disadvantage of the solid source method is also introduced. Corresponding to each of the K_α quanta that are undetected, any L or M quantum that is subsequently emitted by the decaying atom has a chance of being detected, which approaches nearly fifty percent for high pressures of the detector gas. When a gaseous source is used, corrections due to such "escape" events can be serious only when the pressure is such that a substantial fraction of the X-rays leave the counter undetected. This is usually the case only for the K_α quanta due to electron capture from the K shells. In the case

of a solid source, however, such corrections arise more generally, and should be applied for all counter gas pressures and for electron capture from all atomic shells.

Sources which are thinner than monatomic layer can easily be produced by evaporation. The amount of radiactive isotope placed on the heater element of the evaporator should be such that the maximum average thickness of the evaporation deposit at the position of the source-backing film will be less than that of a monatomic layer. Since the source-thickness is not important as long as it is considerably less than that of a monatomic layer, some degree of non uniformity of source-thickness does not present a serious problem. Sources of sufficient strength can be produced in most cases without difficulty, since the method permits the use of a large surface area for the source. Strengths of the order of tenths of a microcurie are easily obtained.

3. VERIFICATION

The contention that the presence of a backing material, as well as the finite thickness of the submonatic layer source, do not alter the spectral features, shall be experimentally verified. For this purpose we constructed a single wire proportional counter consisting of a brass cylinder of 8.9 cms O.D., 5.1 cms I.D., and 51 cms. length, and a stainless steel anode wire of 0.010 cm diameter. Guard rings are provided at the ends of the counter. A longitudinal section of the thick outer brass tube, 2.5 cms wide and 25 cms long (equidistant from both ends of the counter) can be removed if necessary and

refitted when the counter is to be used. The arrangement is made vacuum-tight by means of an O-ring mounted between the main body of the counter wall and the section that can be removed. Sources are mounted on the inner surface of the removable section. An argon-methane mixture is used as the proportional counter gas. The counter can be operated at pressures below and above the atmosphere.

Sources of Fe^{55}, of estimated thickness less than that of a monatomic layer, backed by thin polyethelene film, were prepared by the evaporation method. The spectrum of the X-rays is recorded on a 128-channel analyser. Preliminary data appears to indicate that the contentions presented in this paper are correct. More accurate and conclusive results are expected to be available within a short period. Electron capture-ratios shall be determined for Fe^{55}, Cd^{109}, etc., and compared with results obtained using gaseous sources.